For melt detection, MODIS ice surface temperatures (IST) compare well to NOAA air temperatures (T_A) at Summit, Greenland

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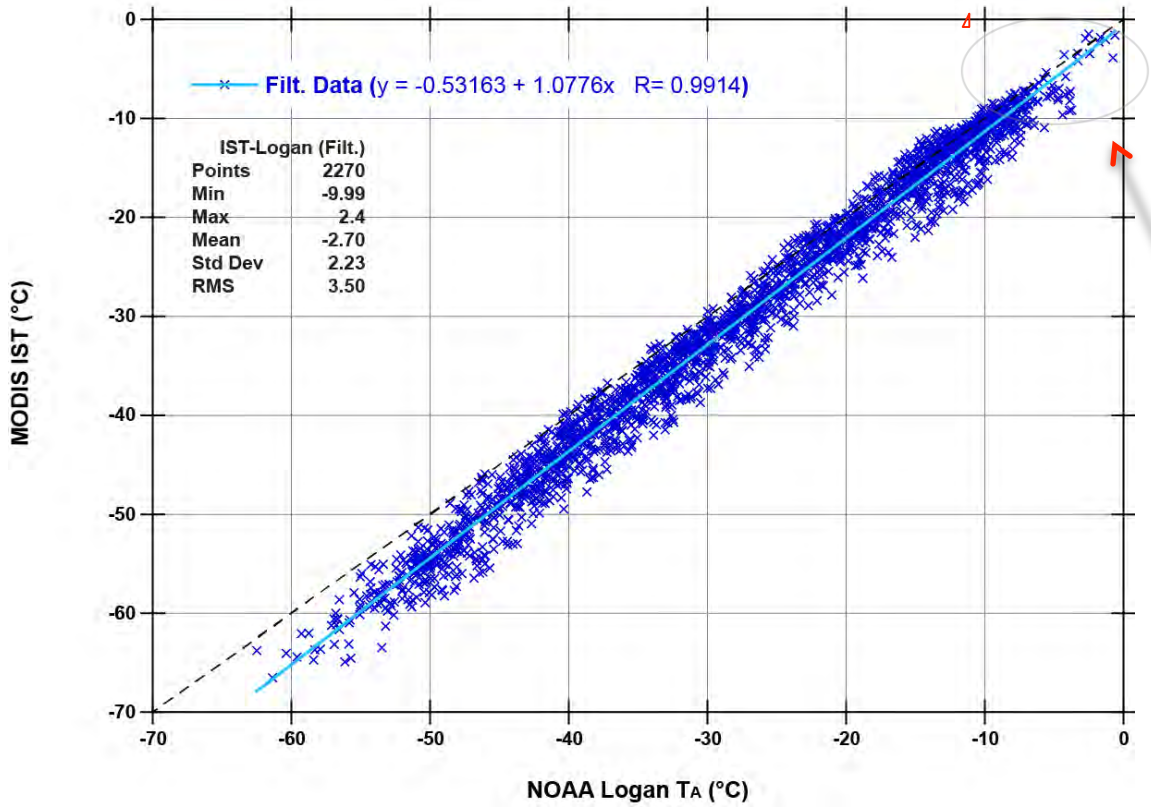
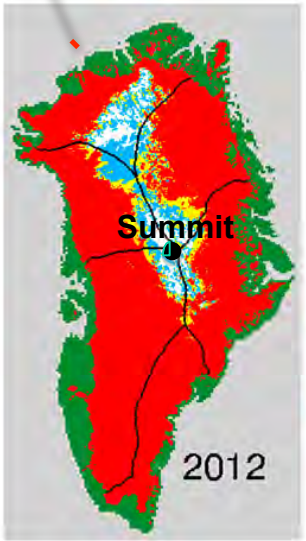
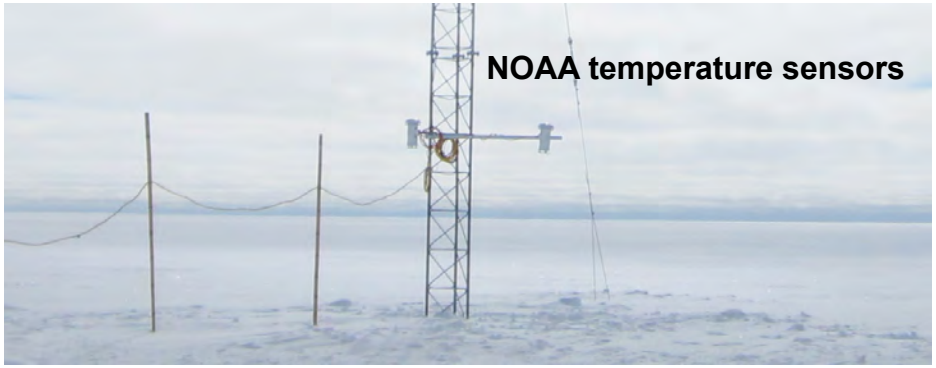


The temperature offset between T_A data from the NOAA station at Summit, and the ice surface temperatures obtained by MODIS is close to −0.5°C near freezing but increases to about −5°C at −60°C T_A.



IST Maximum Melt

- no melt
- 1 day melt
- 2 days melt
- >2 days melt



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References:

Hall, D.K., J.C. Comiso, N.E. DiGirolamo, C.A. Shuman, J.R. Key and L.S. Koenig, 2012: A Satellite-Derived Climate-Quality Data Record of the Clear-Sky Surface Temperature of the Greenland Ice Sheet, *Journal of Climate,* 25(14):4785-4798. doi.org/10.1175/JCLI-D-11-00365.1

Shuman, C.A., D.K. Hall, N.E. DiGirolamo, T.K. Mefford, and M.J. Schnaubelt, in press. Comparison of near-surface air temperatures and MODIS ice-surface temperatures at Summit, Greenland (2008-2013), Journal of Applied Meteorology and Climatology.

Data Sources and Acknowledgments:

The IST data was derived using the MOD29 algorithm over Greenland (Hall et al., 2012). The Greenland data are available from: http://modis-snow-ice.gsfc.nasa.gov/. NASA's Cryospheric Sciences Program provided funding for the MODIS IST dataset as well as the work performed at NASA GSFC and at UMBC. Jack Xiong (GSFC), Brian Wenny (Sigma Space) of the MODIS Characterization and Support Team, and George Riggs (SSAI) provided insights on the IST data and MODIS products. We would like to thank the support staff at the Greenland Summit Station for helping to provide the in situ data necessary for this study. The TA data are from NOAA's Earth System Research Laboratory, Global Monitoring Division data sets.

Technical Description of Figures:

The graph is a scatter plot of the temporally−coincident 2008-2013 IST and TA data (±3-minute averages). A linear regression line is shown for a subset of all the data (blue symbols) after a ±5°C regression filter was applied to reduce the impact of cloud-impacted IST values. The blue regression line suggests that the IST−TA difference is close to zero at freezing and about −5°C at the low end of the temperature range. A zero difference line (both temperature values are equal) is indicated by the black dashed line (Shuman et al., submitted). Statistics for overall differences for the plotted data are also shown. Generally similar results were obtained for each individual year of the study.

Scientific significance, societal relevance, and relationships to future missions:

We have investigated the accuracy of the MODerate−resolution Imaging Spectroradiometer (MODIS) IST product from Terra for use as a climate−quality data record. Our study indicates that IST data are accurate to better than 1°C for melt detection. Accuracy decreases as temperature decreases perhaps due to calibration issues for MODIS bands at extreme cold temperatures. The most practical way to get a spatially−broad and temporally−extensive measurement of surface temperature for an area the size of the Greenland Ice Sheet is through satellite remote sensing. However, the uncertainties in satellite−derived temperatures must be assessed relative to independent TA data sets such as those from well-calibrated weather stations, such as the NOAA station at Summit, to validate them for use in climate studies. Full confidence in these remote-sensing records can be established by comparison to the best available in situ climate data. Evaluating changes in the polar regions is important for understanding the Earth's climate system. This study supports the Decadal Survey goals by improving measurements of ice temperatures and their variation through time.

Effect of snow surface metamorphism on Aquarius observations at Dome C, Antarctica

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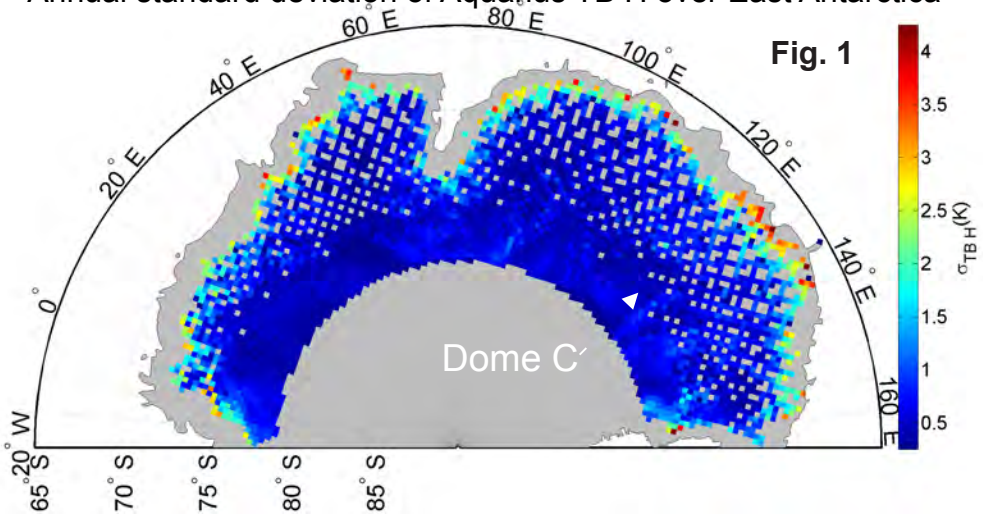
Emmanuel Dinnat, NASA/GSFC, code 615; Chapman University

Annual standard deviation of Aquarius TB H over East Antarctica

Fig. 1



Time series at Dome C

Fig. 2

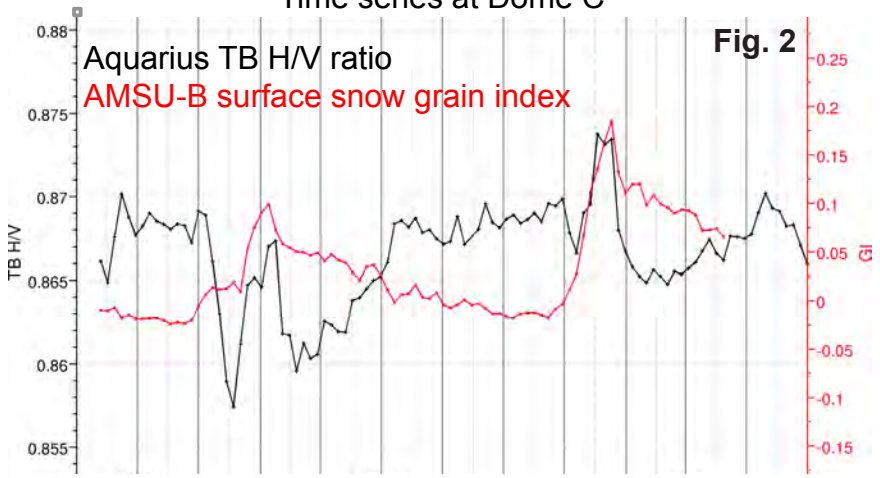
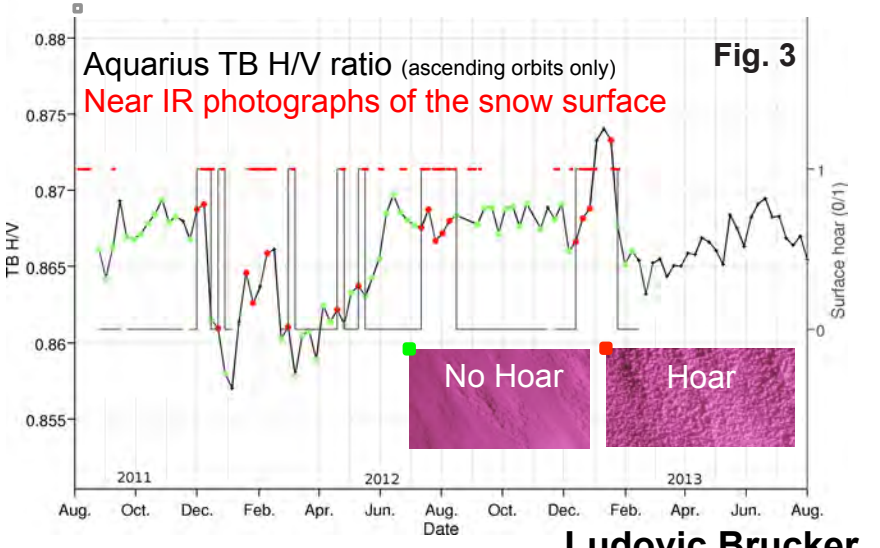


Fig. 3



The annual temporal variability of Aquarius L-band (1.4 GHz) brightness temperature (TB) observations is low over the Antarctic high elevations due to the deep penetration of the L-band radiation in ice (>200 m). However, the analysis of Aquarius TB observations at Dome C revealed significant variations (up to 2.5 K) in summer. These variations are larger than the radiometer sensitivity of ~0.2 K over the ice sheet, and appear correlated with the presence/absence of hoar crystal on the snow surface.

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References: Brucker, L., Dinnat, E. P., Picard, G., and Champollion, N.: Effect of snow surface metamorphism on Aquarius L-band radiometer observations at Dome C, Antarctica, IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 11, pp. 7408–7417, doi:10.1109/TGRS.2014.2312102, 2014

Ghislain Picard and Nicolas Champollion provided the AMSU-B grain index and the surface-based near infrared photographs, respectively. Both are from University Grenoble Alpes/CNRS, LGGE, France.

Data Sources: NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) Aquarius Level 2 (version 3.0) product.

Technical Description of Figures:

Figure 1: Maps of annual standard deviation of Aquarius brightness temperature observations at horizontal polarization over East Antarctica for the year 2012. Areas with melt were masked. Each grid cell has a spatial resolution of 36 km x 36 km.

Figure 2: Changes in the Aquarius TB H/V ratio (black) during the summer are significantly larger than the radiometric noise, and they occur at the same time as AMSU surface grain index changes (red).

Figure 3: The largest and longest temporal variations of Aquarius TB H/V (black) are consistent with the evolution of hoar crystals on the surface (presence (red), absence (green)) monitored from a surface-based near infra-red camera. In this figure, only Aquarius observations from descending orbits were considered.

Scientific significance, societal relevance, and relationships to future missions:

The Antarctic Plateau presents ideal characteristics to study the relationship between microwave observations and snow/ice properties. It is also a promising target for the calibration and intercalibration of Aquarius, SMAP, and ESA's MIRAS/SMOS radiometers. Our investigation correlated the Aquarius L-band radiometric variations and the snow surface properties. We have shown that changes in the snow property on the surface, or very close to the surface (i.e., within the first few cm), do impact the TB observations by a few kelvins (up to 2.5 K). This was done using near-infrared photographs of the snow surface, and AMSU-B grain index. Therefore, a particular attention needs to be paid for the selection of areas and periods for future inter-calibration of the L-band missions over the ice sheets. An improved understanding of the Aquarius L-band observations directly contributes to the forthcoming NASA's SMAP mission, and for possible sensor intercalibration over the Earth's cryosphere.

Weekly gridded Aquarius L-band radiometer/scatterometer observations and salinity retrievals over the polar regions

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Detection of frozen soil

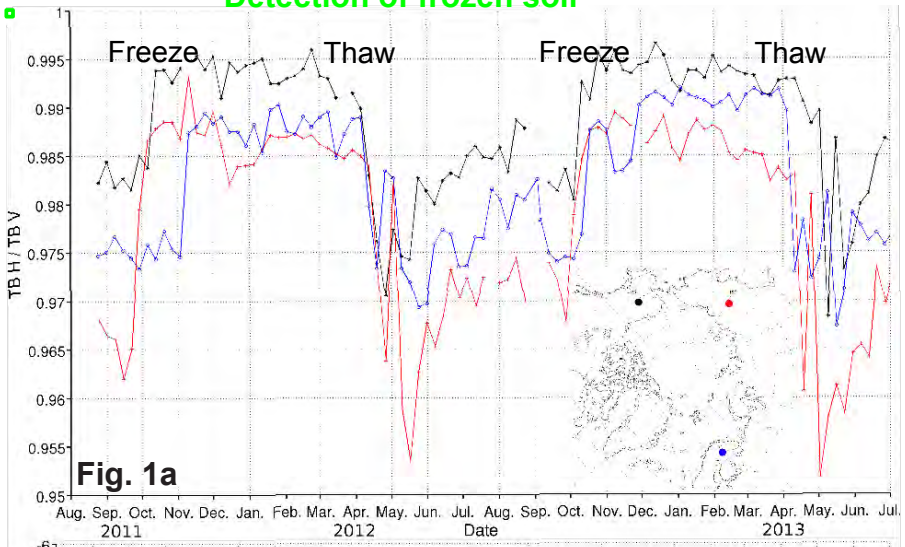

Fig. 1a

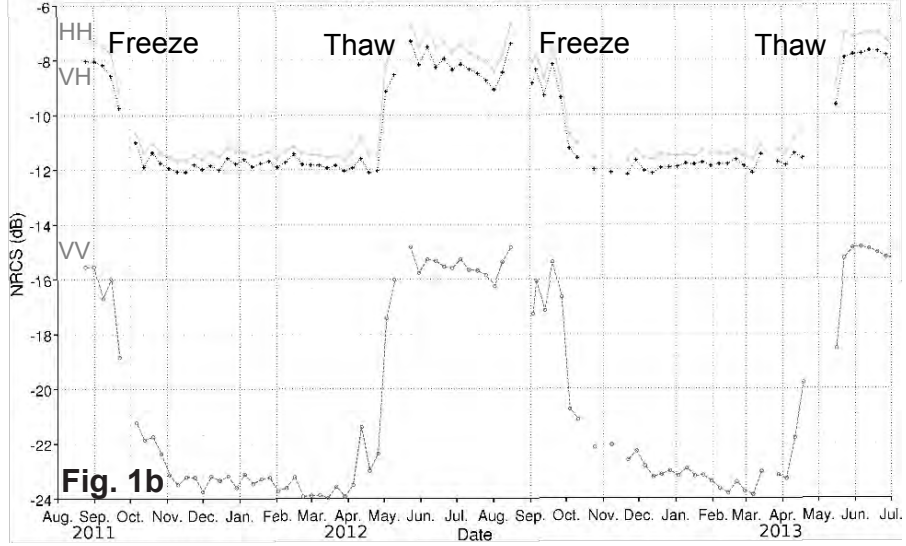

Fig. 1b

Detection of freshening along the coast of Greenland

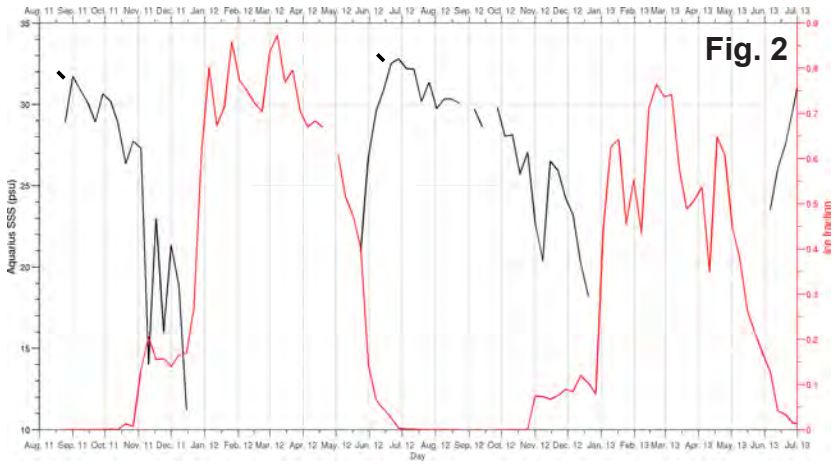

Fig. 2

Detection of the exceptional melt event at Summit, Greenland

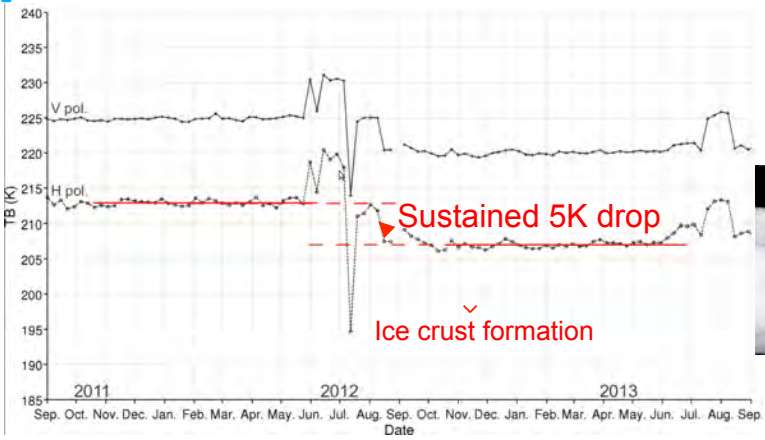

Fig. 3

Aquarius observations enable us to monitor the cryosphere.

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References: Brucker, L., Dinnat, E. P., and Koenig, L. S.: Weekly gridded Aquarius L-band radiometer/scatterometer observations and salinity retrievals over the polar regions – Part 1: Product description, The Cryosphere, 8, 905-913, doi:10.5194/tc-8-905-2014, 2014a.

Brucker, L., Dinnat, E. P., and Koenig, L. S.: Weekly gridded Aquarius L-band radiometer/scatterometer observations and salinity retrievals over the polar regions – Part 2: Initial product analysis, The Cryosphere, 8, 915-930, doi:.5194/tc-8-915-2014, 2014b.

Data Sources: NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) Aquarius Level 2 (version 3.0) product.

Technical Description of Figures:

Figure 1: (Top, 1a) Time series of Aquarius brightness temperature (TB) polarization ratio over three subarctic regions: North America, Northern Europe, and Asia. (Bottom, 1b) Time series of Normalized Radar Cross Section (NRCS) at three polarizations for the location in Asia. This figure illustrates the potential for a combined active/passive monitoring of frozen soil at L band.

Figure 2: Time series of Aquarius retrieved sea surface salinity (SSS) for an off-shore location south west of Greenland. In summer when sea ice is not present, Aquarius has the potential to detect freshening likely initiated by the Greenland ice sheet melt. However, the monitoring of SSS is challenging in cold water with possibly surrounding sea ice and icebergs.

Figure 3: Time series of Aquarius brightness temperature at (top) vertical and (bottom) horizontal polarizations at Summit, Greenland. The exceptional 2012 melt event led to the formation of refrozen ice layers at the surface (enclosed picture; ©Mary Albert), which impacted the Aquarius TB observations with a sustained 5 K drop at horizontal polarization.

Scientific significance, societal relevance, and relationships to future missions: NASA's Aquarius L-band mission was primarily designed for the monitoring of SSS. However, the uniqueness of L-band emission over the polar regions opens new research topics to study the cryosphere:

- Over the ice sheets, L-band observations motivate the development of innovative approaches to study long-term climatic changes. Moreover, specific regions of the Antarctic ice sheet can be used as calibration and validation sites for satellite sensors.
- Over sea ice, L-band radiometric observations contain information about sea ice thickness.
- Over land, the soil physical state (frozen/thawed) can be determined in sub-Arctic environments.

To allow for an efficient use of the Aquarius data over the polar regions, and to move forward our understanding of the L-band observations of ice sheet, sea ice, permafrost, and polar oceans, we developed ***three weekly polar-gridded products*** of brightness temperature (TB), normalized radar cross section (NRCS), and sea surface salinity (SSS). These Aquarius products for the polar regions are ***distributed by the US National Snow and Ice Data Center (NSIDC)***. They intend to facilitate access to L-band data, and can be used to assist in algorithm developments.

Changes in the polar regions have significant consequences for the Earth's climate system. As stated in the Decadal Survey, investigations to understand the interactions between the changing polar atmosphere and changes in sea ice, ocean salinity, and permafrost are important. This study contributes to the Decadal Survey goals of characterizing ice properties, and their changes.

In addition, the availability of these Aquarius products is fundamental to answer high level scientific questions related to the presence of permafrost, and the influence of the melting cryosphere on the ocean properties. These products provide valuable data for the development of satellite algorithms and the preparation of the NASA Soil Moisture Active/Passive (SMAP) mission.